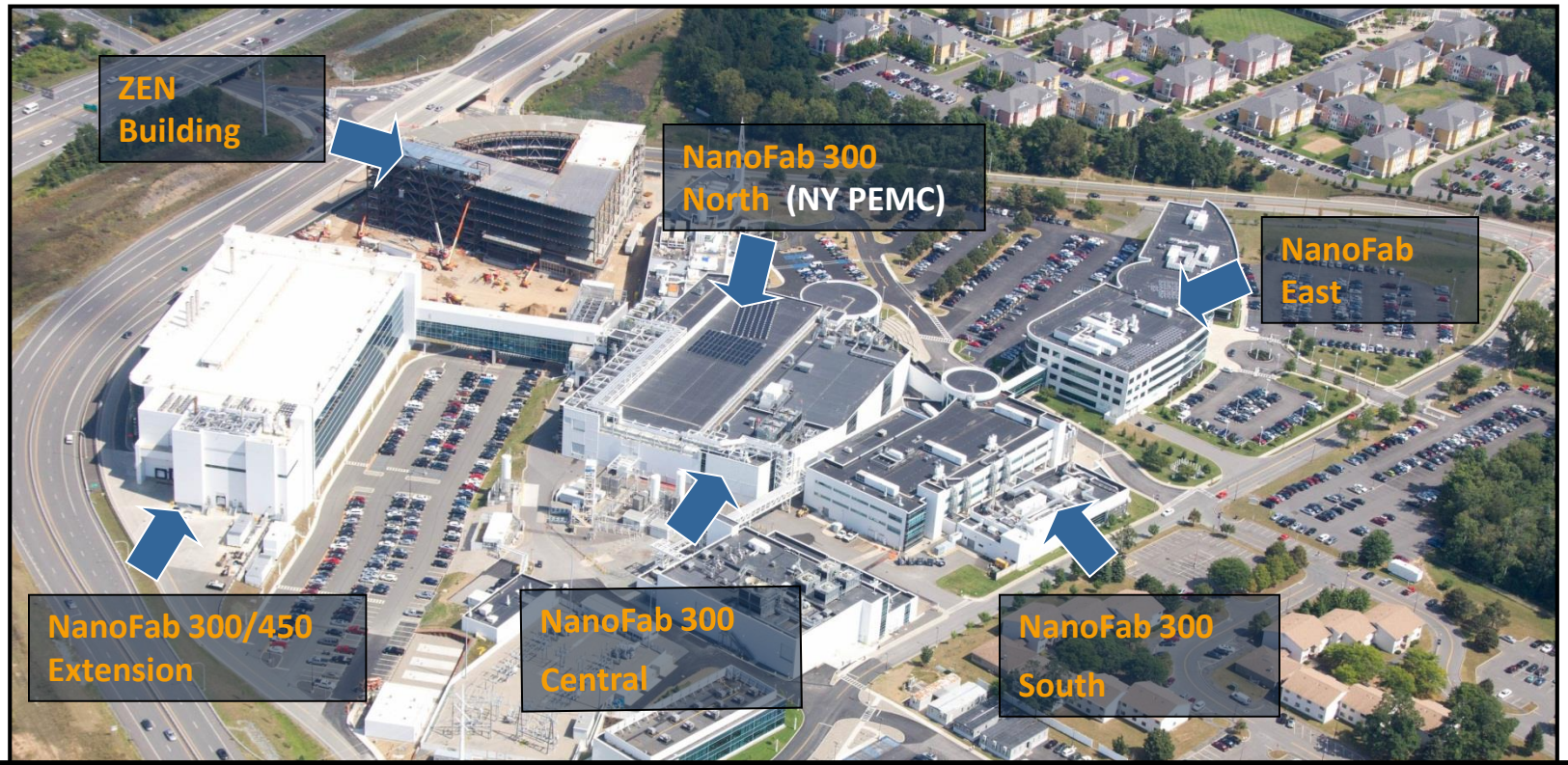
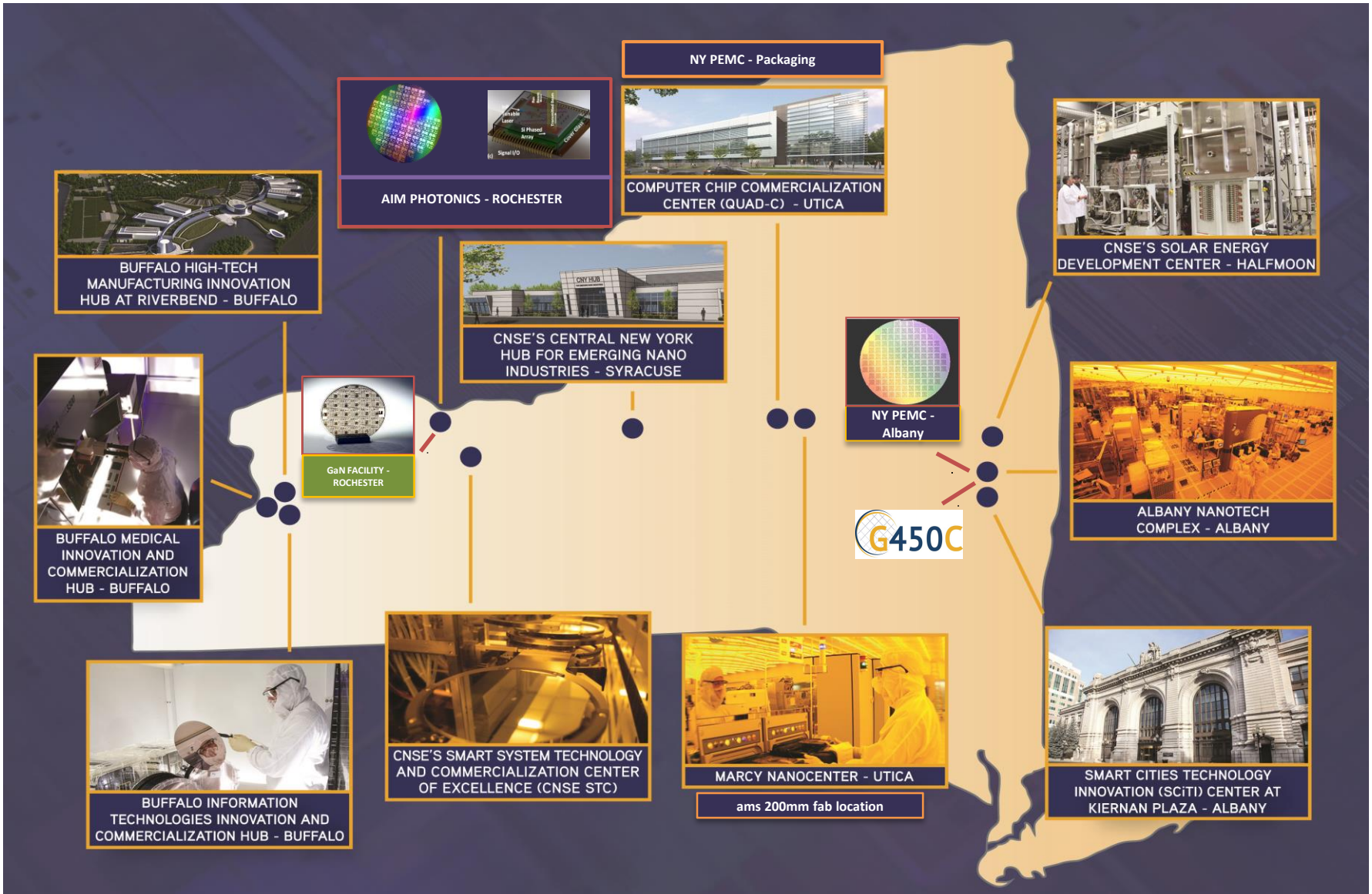
450mm Productivity

Paul A. Farrar Jr.
Global 450mm Consortium
SEMICON Europa

Albany NanoTech Complex



- > 1,000,000 sq.ft. of cutting-edge facilities, with 135,000 sq. ft. of 300mm and 450 mm cleanrooms with a current expansion to 1,300,000 sq. ft.
- More than 300 industry partners including electronics, energy, defense & biohealth
- Over $20Bil investments and over 3,100 R&D jobs currently on site

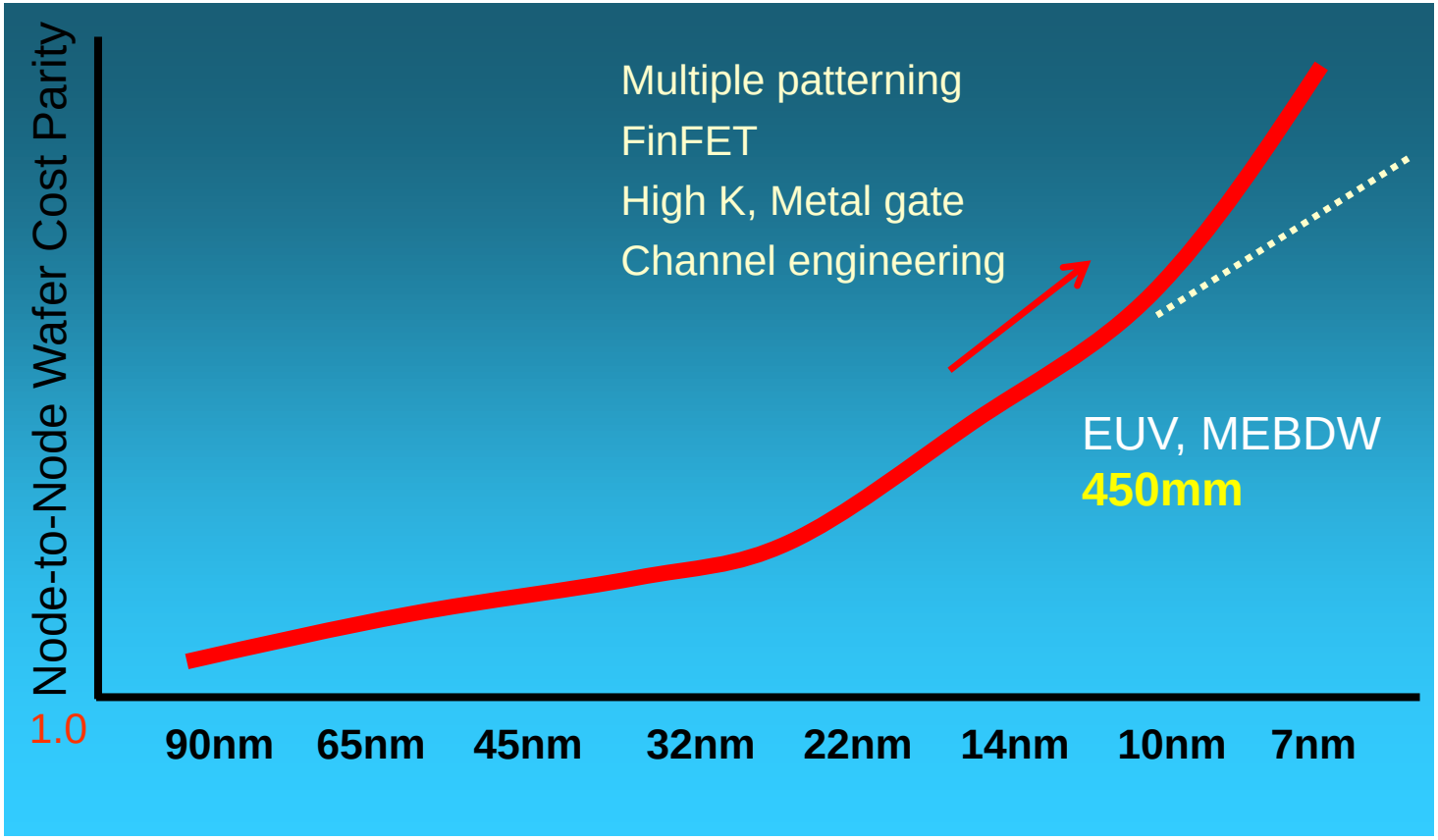

NY PEMC - Packaging
AIM PHOTONICS - ROCHESTER
COMPUTER CHIP COMMERCIALIZATION CENTER (QUAD-C) - UTICA
CNSE'S SOLAR ENERGY DEVELOPMENT CENTER - HALFMOON
BUFFALO HIGH-TECH MANUFACTURING INNOVATION HUB AT RIVERBEND - BUFFALO
CNSE'S CENTRAL NEW YORK HUB FOR EMERGING NANO INDUSTRIES - SYRACUSE
NY PEMC - Albany
GaN FACILITY - ROCHESTER
BUFFALO MEDICAL INNOVATION AND COMMERCIALIZATION HUB - BUFFALO
G450C
ALBANY NANOTECH COMPLEX - ALBANY
CNSE'S SMART SYSTEM TECHNOLOGY AND COMMERCIALIZATION CENTER OF EXCELLENCE (CNSE STC)
MARCY NANOCENTER - UTICA
ams 200mm fab location
SMART CITIES TECHNOLOGY INNOVATION (SCiTI) CENTER AT KIERNAN PLAZA - ALBANY
BUFFALO INFORMATION TECHNOLOGIES INNOVATION AND COMMERCIALIZATION HUB - BUFFALO

Outline

- Benefits of Wafer Size Increase
- 450mm Challenges and Opportunities
- G450C Program Technical Achievements
  - Process Developments
  - Tool improvement
  - Notchless Wafer and Quality
- Cost Savings of 450mm
- Outlook for 450mm and Summary

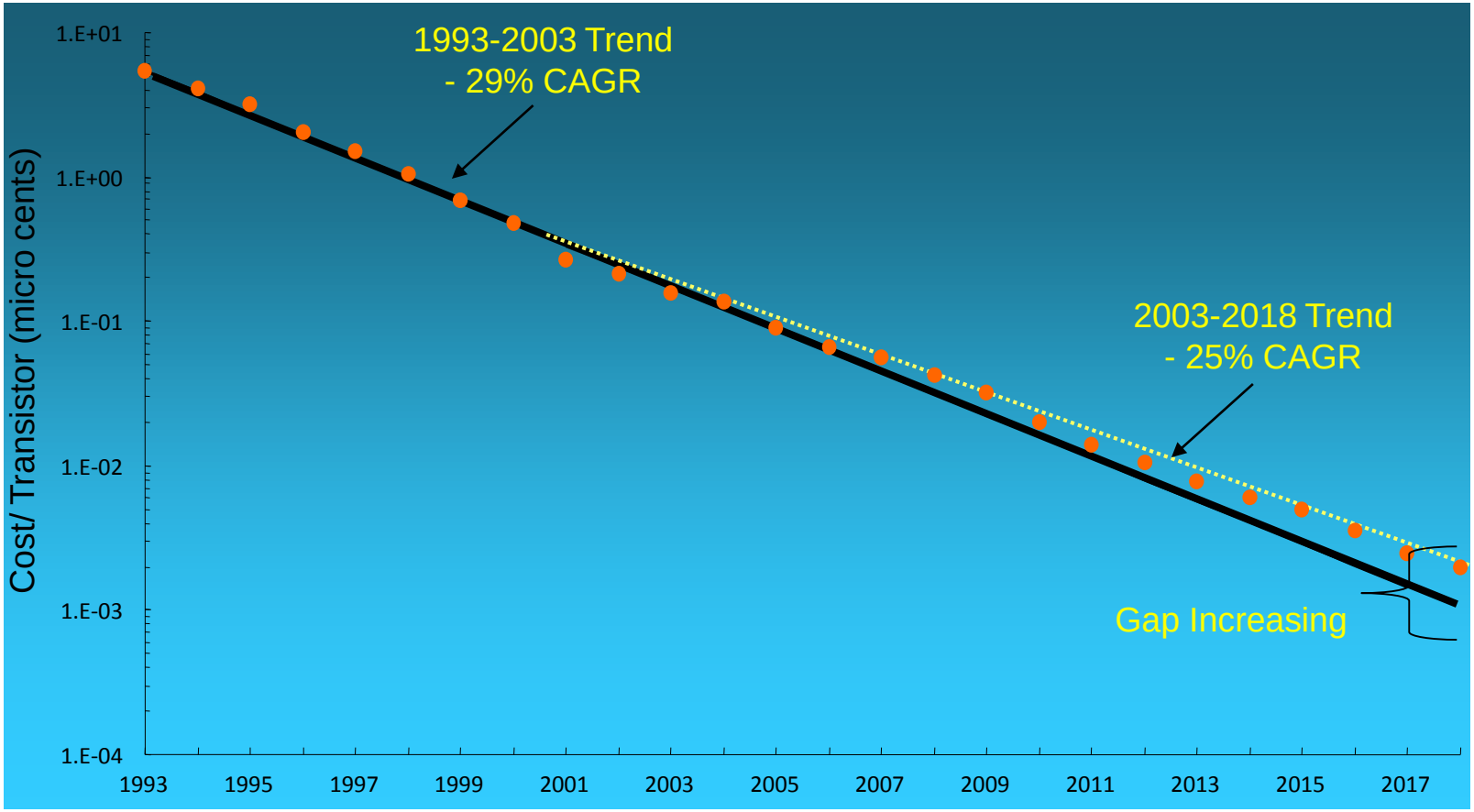
Cost Increases Rapidly by Technology Complexity

- Technology shrink from node to node increases complexity and cost



Cost per Transistor Reduction Slows Down

- Cost /transistor reduction trend cannot be maintained due to increase of technology complexity and slowing pace of technology shrink



Source: ISMI 1993-2013; projected 2014-2018

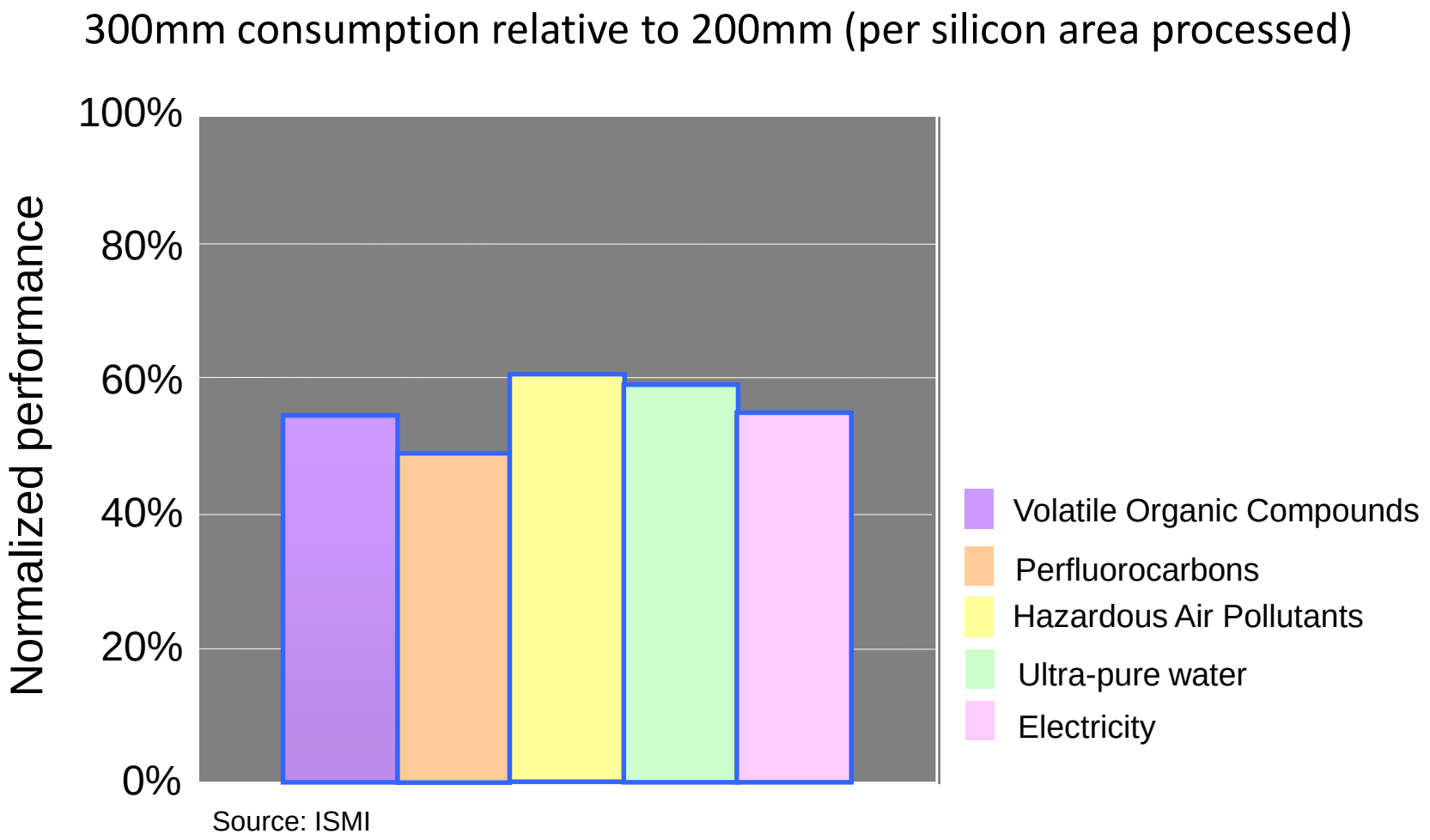
Expect Similar Benefits for 450mm Transition

- Many innovations enabled 300mm transition

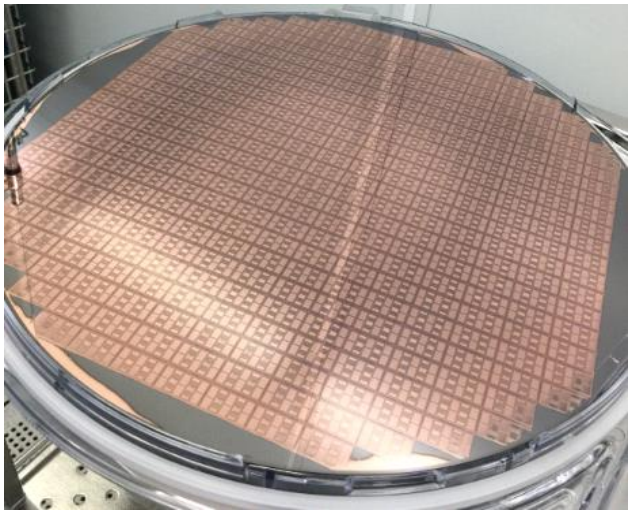
Production Indices Summary 300mm vs. 200mm	
Cycle Time	0.8X
Defect Density	0.4X
People Productivity	2.5X
Equipment Productivity	1.8X wph
Green – energy/water/material	0.5~0.7
Full Automation rate	Semi → Full Auto

Large Wafers Provide Green Fab

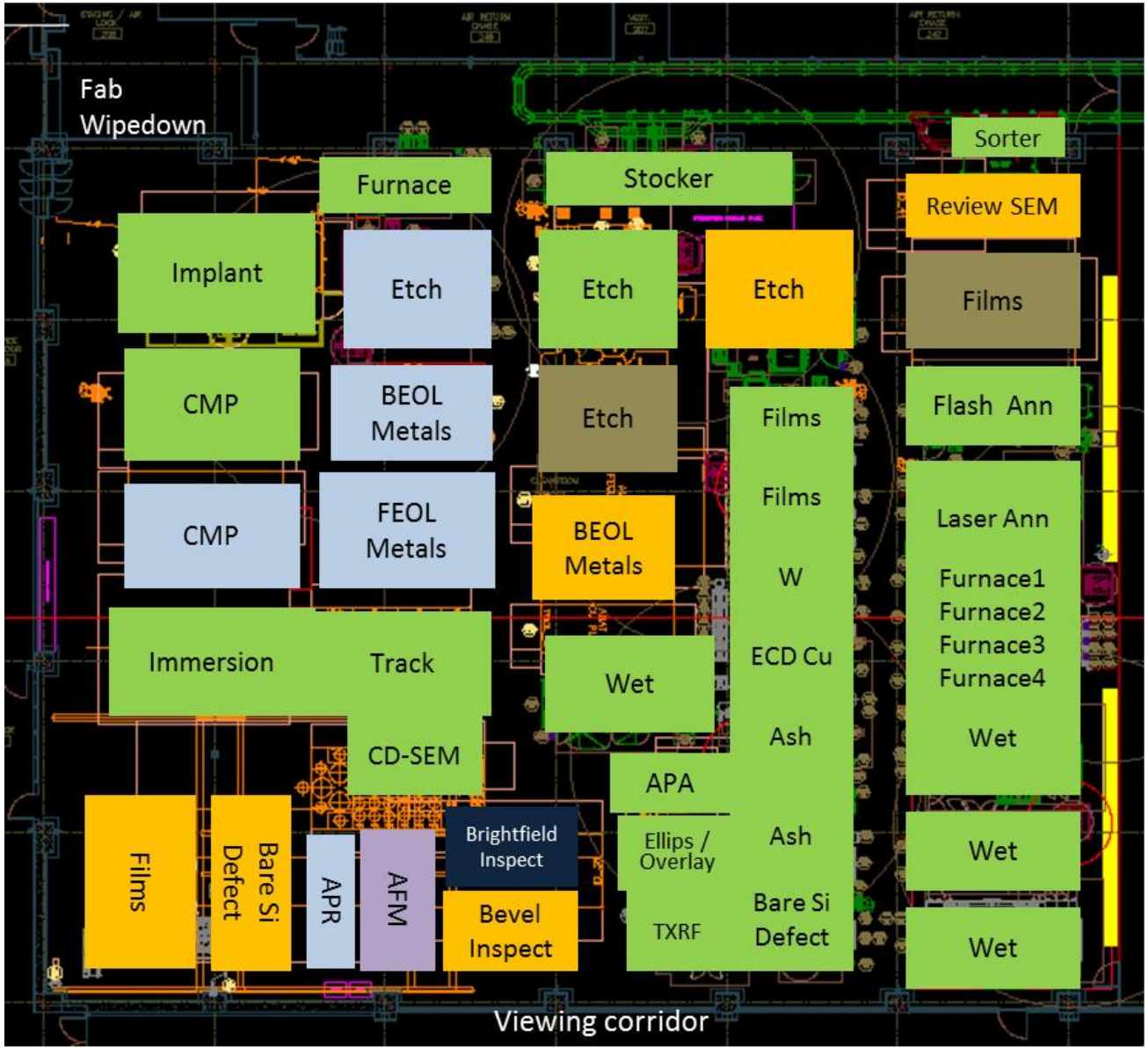
- Expect the similar green efficiency from 450mm transition
  - EPM: 1:1 consumption from 300mm to 450mm goal



- Collaboratively work with Industry Suppliers and IDMs to develop and test 450mm equipment and build up infrastructure to meet industry needs
- Consists of 5 member companies (Intel, TSMC, GLOBALFOUNDRIES, IBM, Samsung) and New York State partnering with SUNY Poly
- Full flow 14nm/10nm and beyond capability by 2016
- Over fifty 1st of a kind tools on-site



G450C Tool Installation Status



Installed

Active Install

2015

2015 NFN RELO

2016

TBD

450mm Process Tools

Challenges

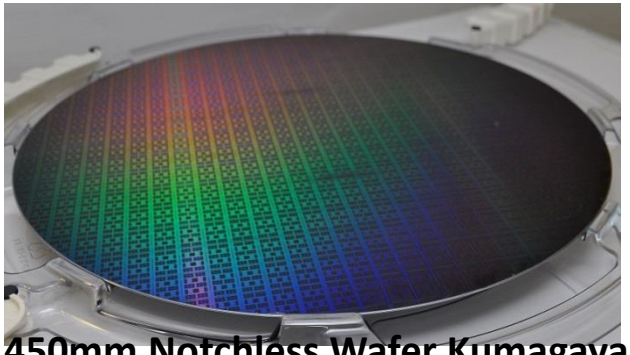
- Uniformity
- Productivity of scanning type of tools
- Foot Print
- Development cost
- HVM timing

Opportunities

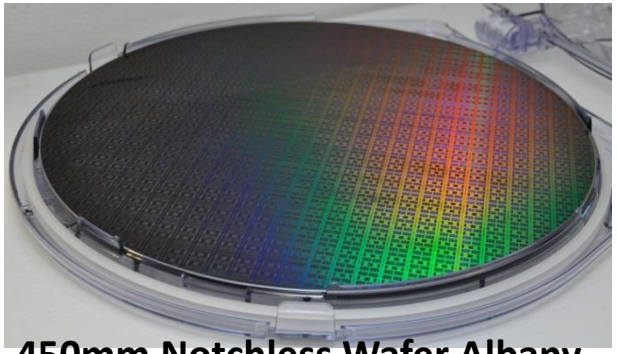
- Cost reduction per area
- New platform
- Stimulate innovation (can even benefit 300mm)
- Greener by area

Litho Process Update

- First dynamically scanned 450mm notchless wafers patterned successfully at Nikon in Japan and demonstrated at SEMICON West 2015
  - Wafers have 1.5mm edge bead and patterned with G450C mask 40nm 1:1 line/space



450mm Notchless Wafer Kumagaya



450mm Notchless Wafer Albany

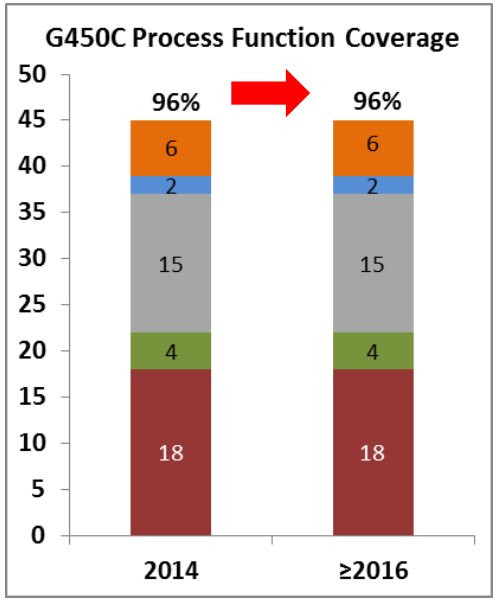
- Final virtual processing of patterned wafers completed at Nikon & Screen in Japan
  - A total of 132 wafers have been virtually patterned to date
    - Multiple processes successfully tested including: 40nm 1:1 L/S & C/H, 28nm & 40nm pitch registered lamella DSA

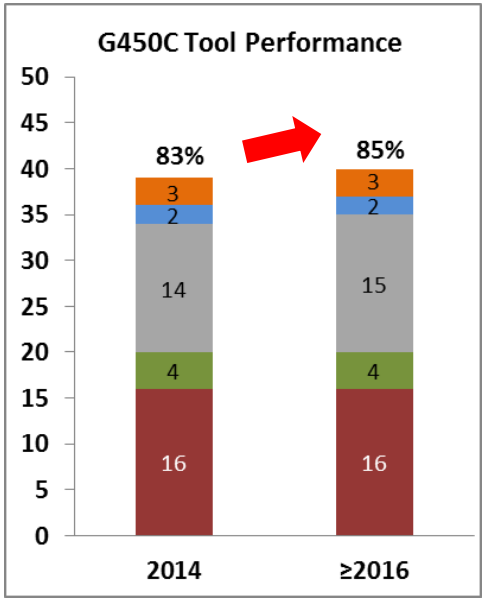
- Screen Coat/Develop Track installation at G450C completed
  - Resist & underlayers installed and tested successfully; developer setup and tested
  - Inline processing from Screen track to Nikon exposure tool setup and tested successfully
    - First wafers patterned successfully through photo cluster
  - 450mm temperature sensing wafers acquired from SensArray and successfully used to verify hotplate settings

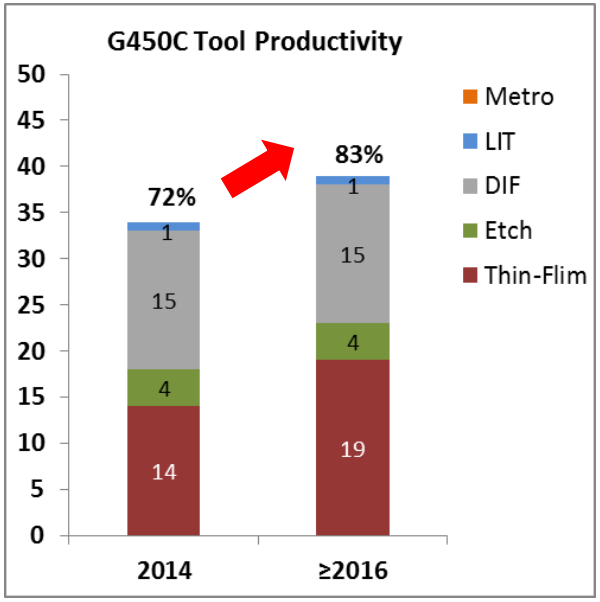
Scanner/Track/Gigaphoton Laser

450mm Tool Readiness Forecast

- Continue good progress in 450mm tool development
  - Tool process function coverage rate: 96% (45/47) → 96% ≥2016
  - Tool performance with high confidence level: 83% (39/47) → 85% ≥2016
  - Tool productivity with high confidence level: 72% (34/47) → 83% ≥2016

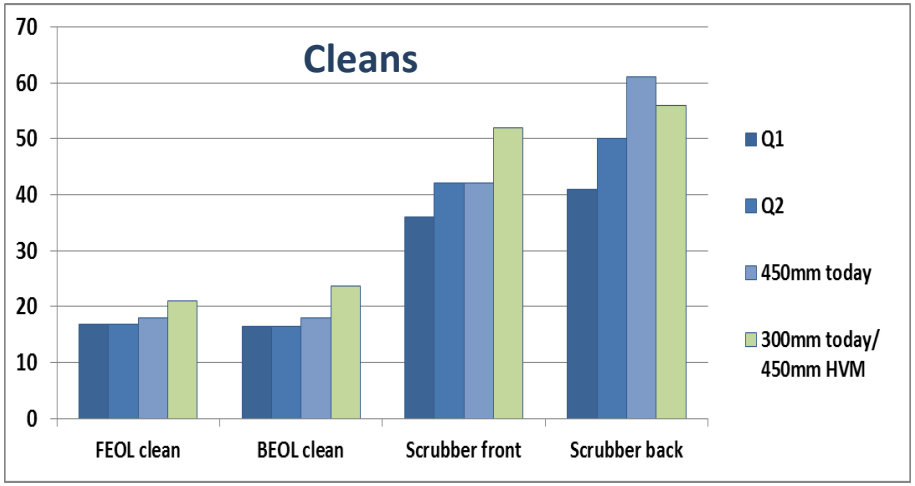


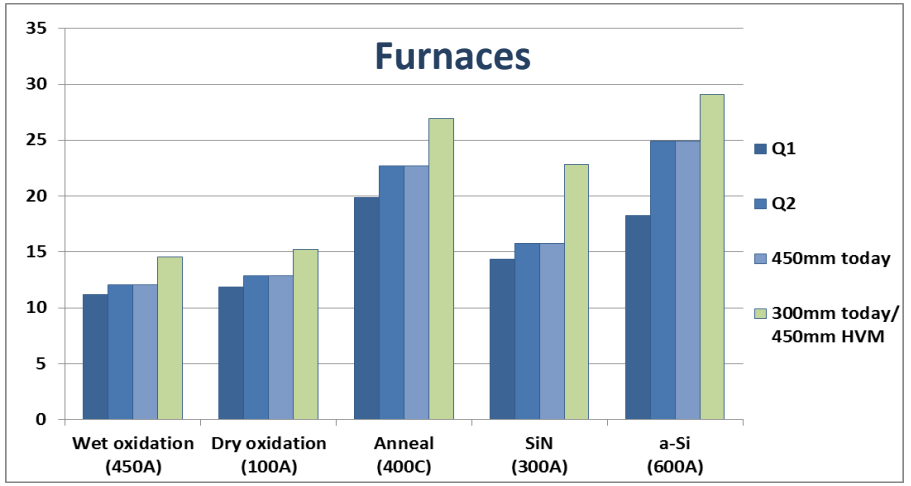




Thermal & Clean Throughput Enhancements

- **Achieved 2015 goal of throughput improvement on cleans**
  - Backside scrubber achieved 49% WPH improvement from POR (41→61) and 14% better than 300mm's by short dry and dual brushes designs.
  - Average 14% WPH improvement from POR on FEOL clean / BEOL clean / front side scrubber is a result of IPA / dry time & spin speed deceleration optimization.
  - Spin motor/ base/ cup & dual spray redesigns planned for HVM.
- **Planed next steps for throughput improvement on thermal furnaces**
  - Average 20% WPH improvement from POR on 5 major thermal processes by cool down time reductions and boat-down speed increases.
  - Projected to improve – temperature stabilization times, elevator boat-up speeds and vacuum stabilization times to improve WPH in the next quarter.
  - Received "TC wafer" to study actual temperature variations at the wafer surface.

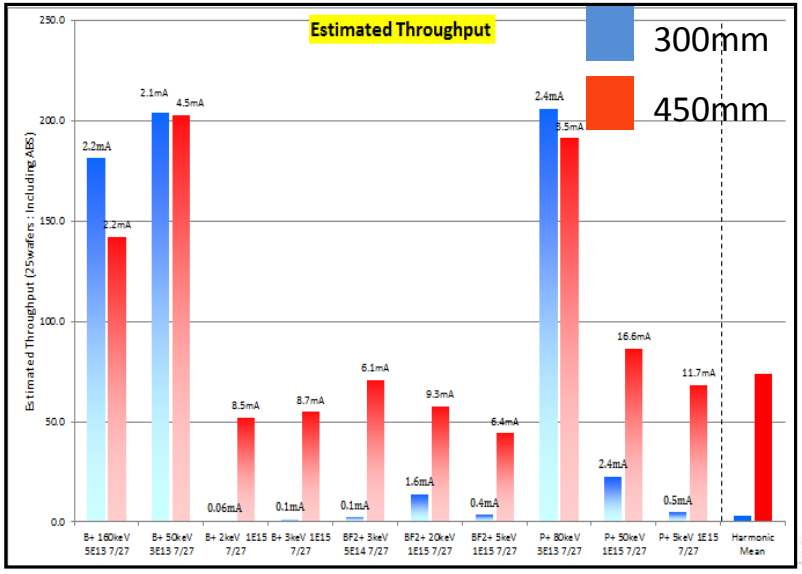




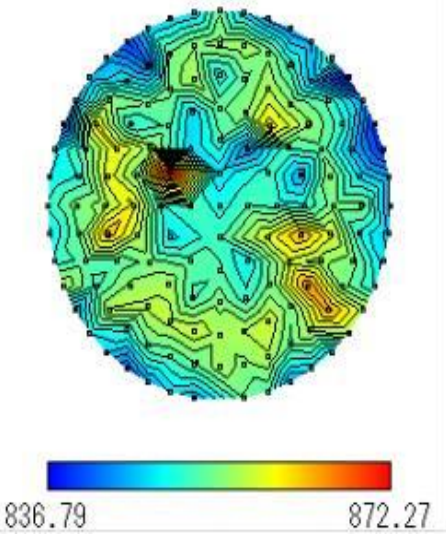
450mm Medium Current Implant

- **Throughput: x1.07 than 300mm**
  - **Beam current increase ~50% @ low dosage recipe.**
- **Blanket wafer performance is comparable with 300mm**
- **Consequently to develop 300mm tool w/i same concept**

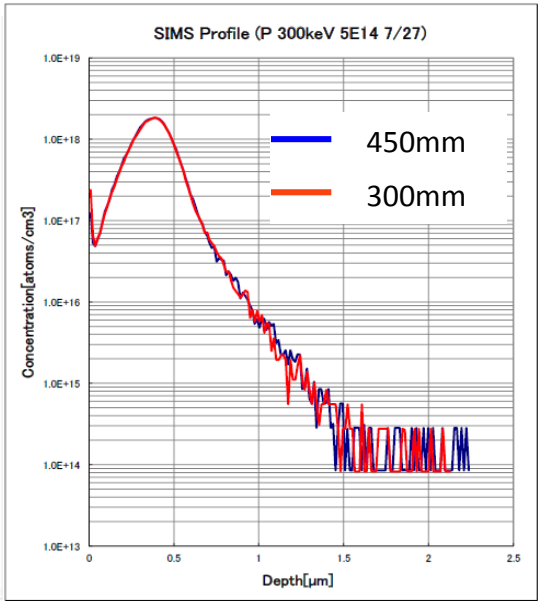
WPH & Beam Current



Rs Map
0.66% 1σ

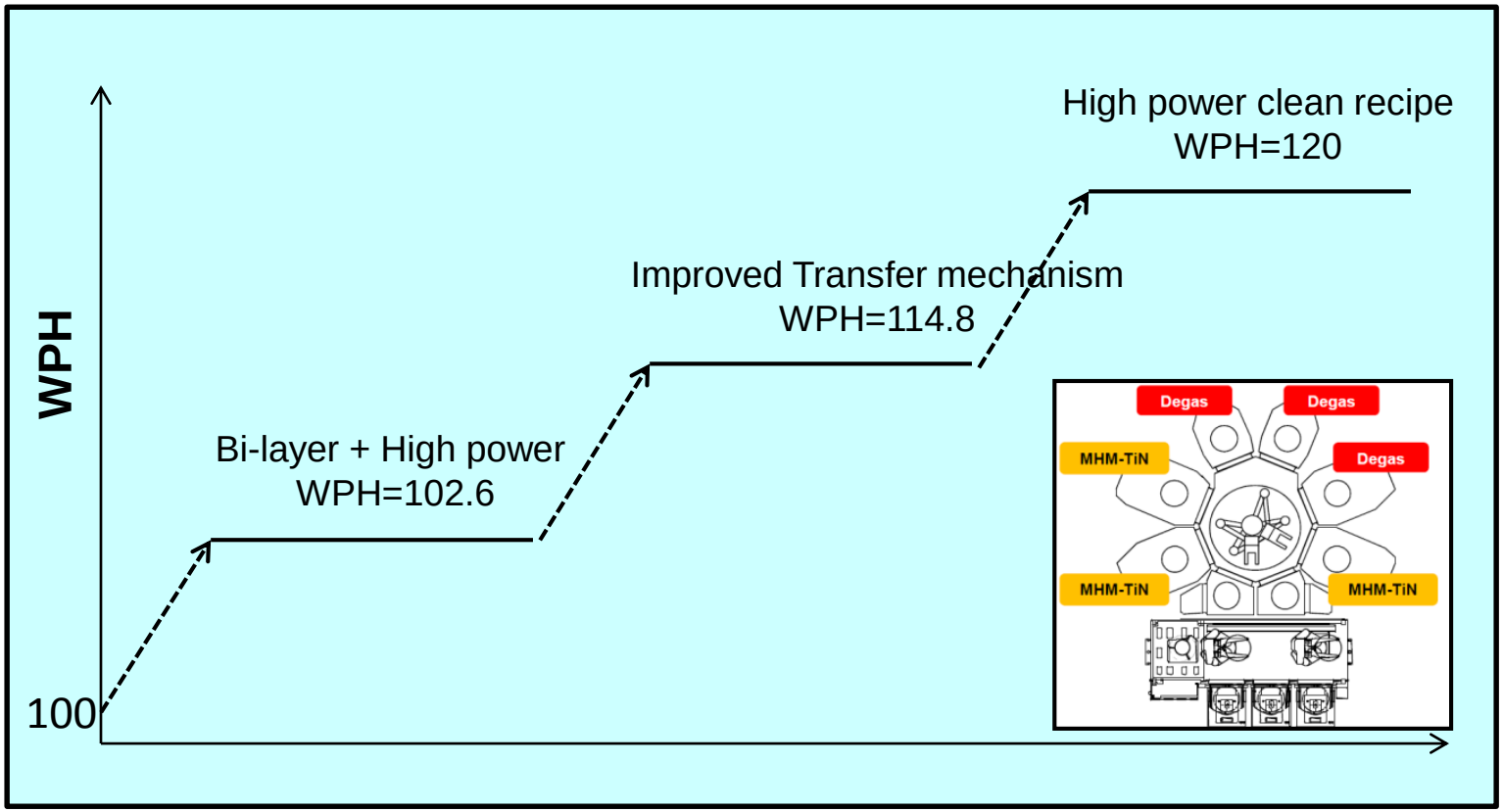


SIMS Profile



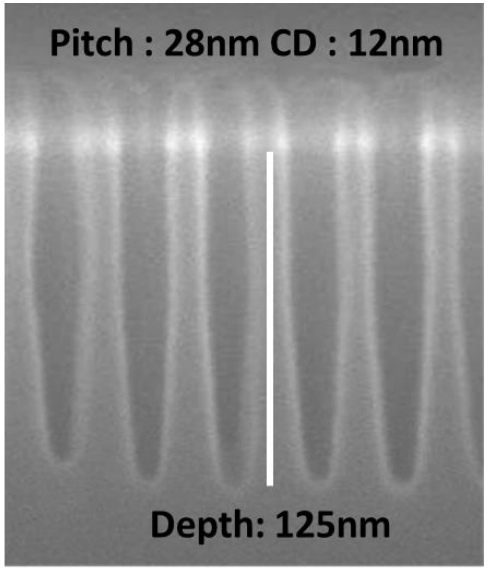
450mm PVD MHM (TiN) Process Update

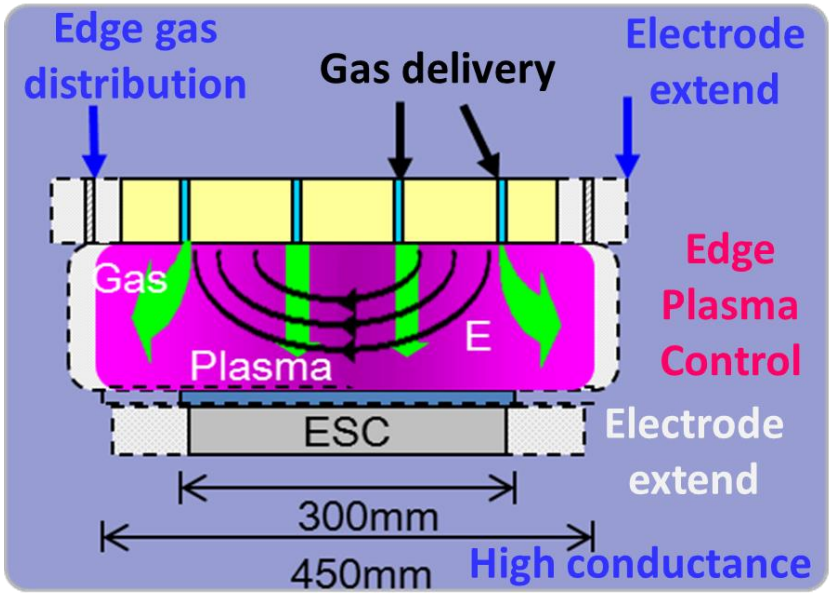
- **Positive 450mm CIP to advance 300mm productivity, WPH ↑ 20%**
- **Activities on 300mm tools (100→120)**
  - Bi-layer (Ti+TiN) + High Dep. power (7→14kw) recipe, WPH 100 → 102.6
  - Improved transfer mechanism, WPH ↑ 114.8.
  - Optimized high power Clean recipe, WPH ↑ 120.

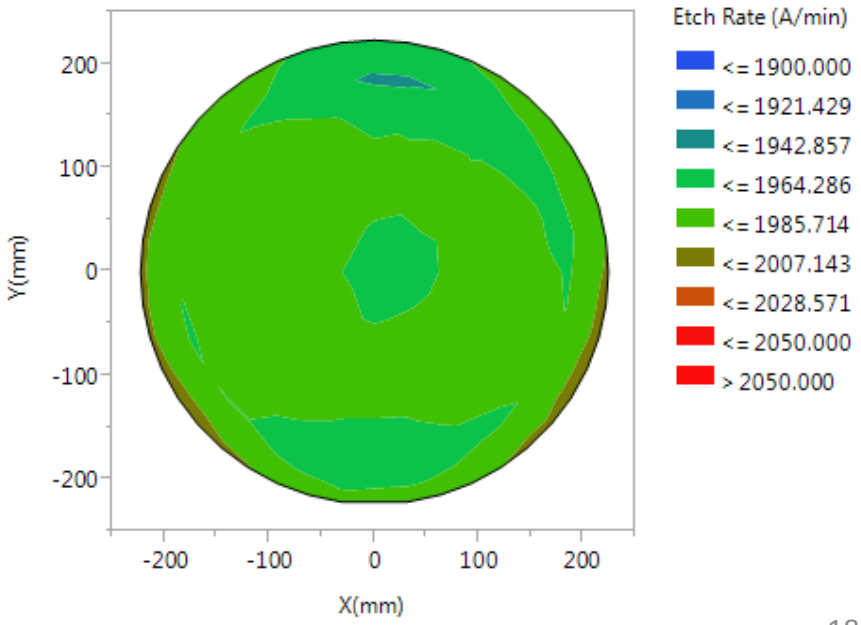


450mm Etch Achievements/Opportunities

- High chamber conductance, symmetric electric, uniform gas flow designs have been successfully demonstrated
- Etch rate uniformity reach to 2.4% (3σ, poly) with 1.5mm edge exclusion

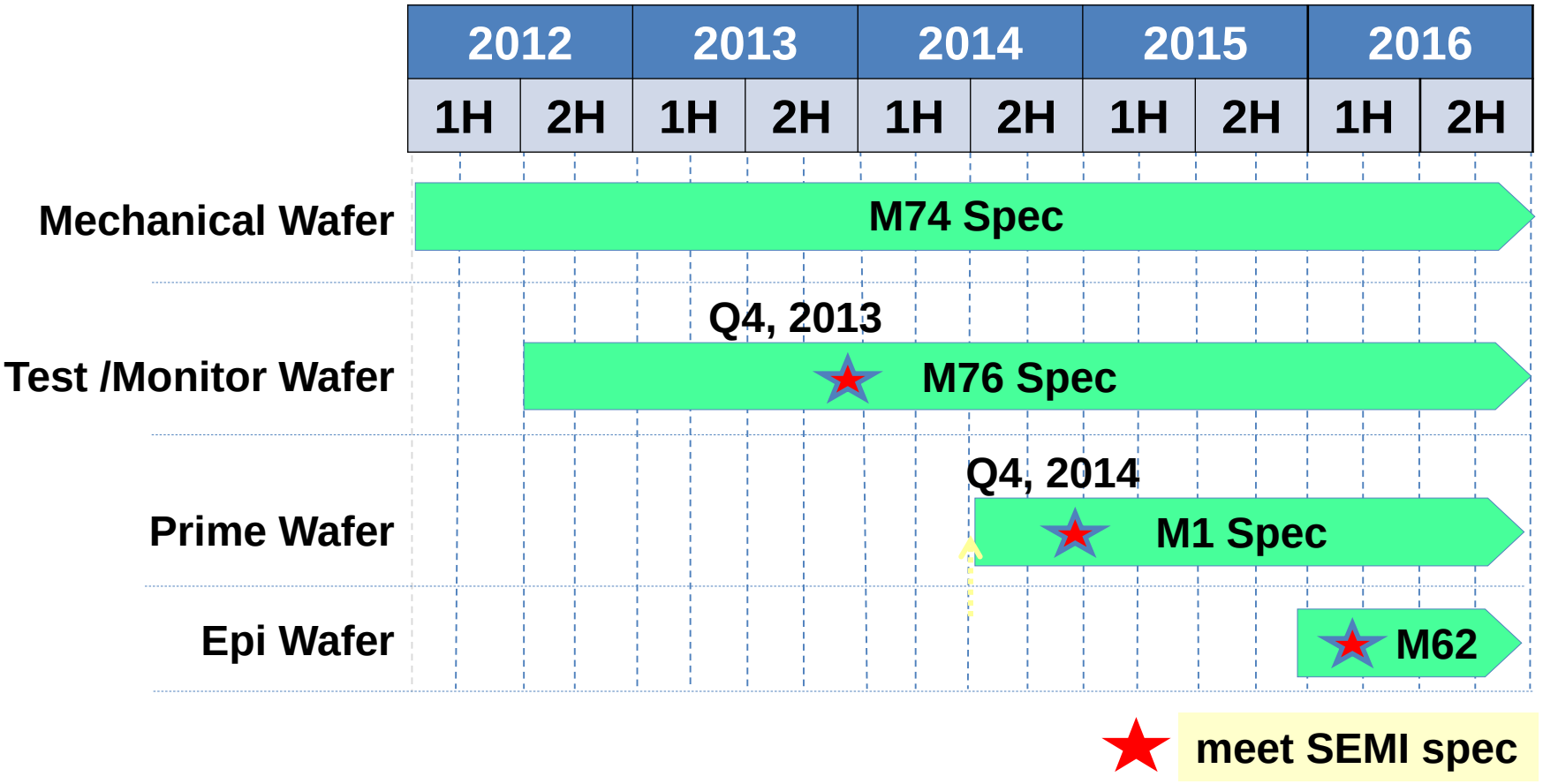






450mm Wafer Progress Update

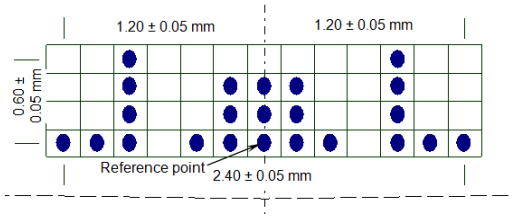
- Wafer quality roadmap: M1 prime wafer spec has been achieved

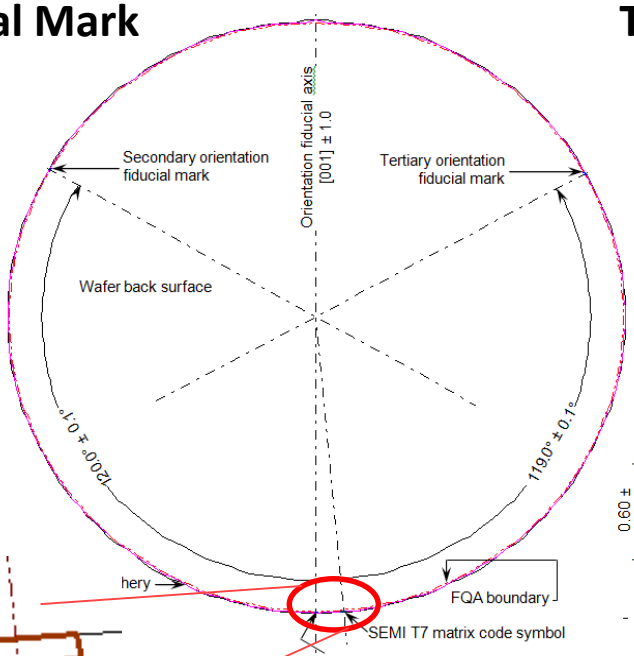


450mm Notchless Wafers/1.5mm Edge Exclusion

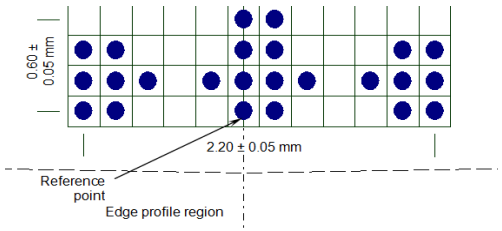
- Industry-wide collaboration for SEMI standards
  - >20 companies, >170 conference calls/meetings, and ~2 years of effort
  - Three Orientation Fiducial Marks made by laser, 1.5 mm from edge
  - Fiducial marks designed for fast, accurate, reliable detection.
  - Net 2% productivity improvement (chips per wafer)

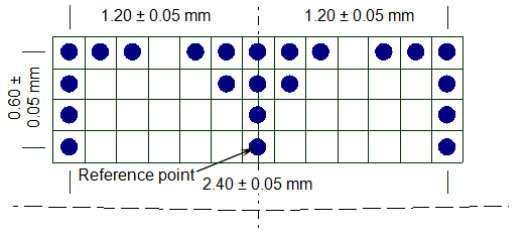
Secondary Orientation Fiducial Mark

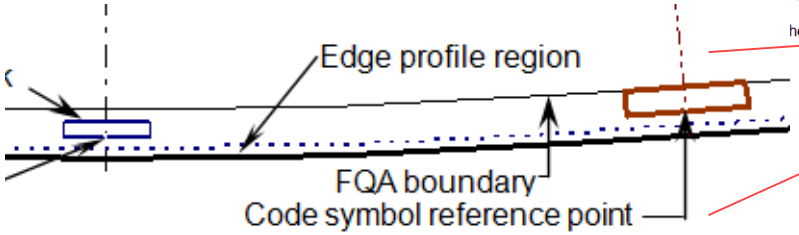




Tertiary Orientation Fiducial Mark







Primary Orientation Fiducial Mark

Key Messages

- 450mm readiness:
  - Process Capability demonstrated on 98% 14nm process steps
  - Productivity: 80% of process tools can achieve 300mm equivalent or better (WPH)
  - Performance: Process tools at or near 300mm process targets
  - Suppliers can deliver HVM tools in 18-24 months after signals
  - Potential die cost savings of >30% achievable

- All G450C member companies want to keep a viable option for 450mm, and consider 450mm a strategic opportunity.